MRI IMAGING OF PANCREATIC DISEASE

Koenraad Mortele, MD

Associate Director, Division of Abdominal Imaging and Intervention & Director, Abdominal and Pelvic MRI, Department of Radiology, Brigham and Women's Hospital
Associate Professor of Radiology, Harvard Medical School

Abstract

Pancreatic imaging is an essential tool in the early diagnosis and staging of pancreatic disease. This presentation reviews the most recent advances in pancreatic MR imaging. The specific modalities discussed include magnetic resonance imaging (MRI), and magnetic resonance cholangiopancreatography (MRCP), before and after secretin stimulation.

Introduction

With the advent of newer imaging techniques, radiologists can now choose among several noninvasive imaging modalities for evaluating patients with suspected pancreatic disorders. Pancreatic imaging is an essential tool in reaching early diagnosis of pancreatic diseases, particularly pancreatic adenocarcinoma, where early diagnosis may lead to improved survival among patients whose prognosis would otherwise be dismal. Unfortunately, preoperative imaging based staging has two major limiting factors: (1) the inability to accurately judge the degree of tumor invasion or encasement of vascular structures and (2) the sometimes subtle extension of the tumor into surrounding peri-pancreatic tissues and invasion of non enlarged lymph nodes.

In this presentation, the MR imaging findings of pancreatic adenocarcinoma and other pancreatic neoplasms, such as endocrine tumors and cystic neoplasms, are illustrated. Furthermore, the imaging characteristics of inflammatory processes, such as chronic and acute pancreatitis, are also highlighted.

Magnetic Resonance Imaging

Pancreatic Ductal Adenocarcinoma

With recent advances in examination techniques, the diagnosis of ductal adenocarcinoma using MRI has improved. Actually, detection of pancreatic adenocarcinoma is based on non-contrast T1 weighted fat-suppressed images and immediate post-gadolinium T1-weighted spoiled gradient echo images. Pancreatic cancer appears as low signal-intensity masses on T1-weighted fat suppressed images, and small tumors are clearly separated from normal pancreatic tissue, which is high in signal intensity.

Post-gadolinium breath-hold gradient echo images are key to detect both hepatic metastases as well as small pancreatic tumors. Recent studies have compared the accuracy of MRI in staging pancreatic carcinoma with helical CT. With breath-hold imaging and the use of phased array coils dynamic MRI was shown superior to helical CT in determining the degree of tumor extension, while both modalities performed equally well in establishing the degree of vascular involvement. Other studies indicate that the two modalities perform comparably in the global assessment of resectability.

In the last few years, the liver-specific MR contrast agent Mn-DPDP has been used for pancreatic MRI. Normal pancreatic tissue becomes hyperintense on T1-weighted images following intravenous administration of Mn-DPDP. Hence, unenhanced pancreatic ductal adenocarcinoma can be delineated from normal pancreas. This appears particularly useful in diagnosing smaller tumors and in differentiating pancreatic carcinomas from chronic pancreatitis. Rieber A et al. recently compared Mn-DPDP enhanced MR and spiral CT in the detection of pancreatic tumors. The results showed that spiral CT is superior to Mn-DPDP enhanced MR in detection of pancreatic tumors, with a respective sensitivity of 100% and 87.5%, specificity of 75% for both, and a respective accuracy of 85% and 80%. Despite the clearly superior results of CT, Mn-DPDP was still considered an effective adjunctive tool in reaching an accurate diagnosis of a lesion. Moreover, Mn-DPDP administration significantly increased the image quality of MRI examination. In 66.7% of cases MR image quality was equivalent to that of spiral CT, and in 11.1% of cases, MR images were considered superior to CT images, especially with respect to the clarity with which the lesion was delineated. Thus, although Mn-DPDP increases the reliability of using MRI in detection of pancreatic carcinoma, Mn-DPDP enhanced MRI seems to be less sensitive than spiral CT. However, the data of these study need confirmation due to the limited patient sample.

MR cholangiopancreatography (MRCP) has proven an accurate means of evaluating the level and causes of pancreatic ductal obstruction. A major advantage of MRP is that the visualization of the duct is based on the signal features in the pancreatic secretions. Thus, one can visualize the duct *before and after* an obstructing lesion occurs. In fact, the duct fluid can provide additional image contrast with which to visualize a non-gland-deforming tumor. MRCP is obtained using heavily T2-weighted sequences. The ultra-fast half-Fourier single-shot turbo-SE (HASTE) sequence allows for rapid acquisition on T2-weighted images, using a single-shot acquisition strategy. Although a 20-slice acquisition is well within the breath-hold capabilities of most patients, the ability to perform a breath-hold is not a strict requirement for obtaining diagnostic images. Thus, HASTE is especially useful in somnolent and uncooperative patients. The availability of HASTE sequences has significantly shortened the overall examination time. Using another T2 technique that relies on thick section, a long echo train, and single-shot technique, a very heavy, T2-weighted image that emulates the appearance of an endoscopic retrograde cholangiopancreatography (ERCP) can be generated. This so-called "thick" T2-weighted MR approach is especially sensitive to fluid, a characteristic that can also create interpretation problems because high signal intensity is produced not only for the cholangiographic tract, but also for the intra-gastrointestinal tract liquid component. Theoretically, a gastrointestinal T2-shortening negative contrast agent should be useful in minimizing this problem when coupled with these techniques.

As mentioned previously, MR cholangiopancreatography (MRCP) has been proven accurate in the evaluation of the level and cause of pancreatic ductal obstruction. Recently, Arslan A. et al. retrospectively reviewed 153 patients to compare the diagnostic value of MRCP to that of ERCP in the diagnosis of various obstructive and non-obstructive pancreatobiliary diseases. The concordance between the two tests was very high. The accuracy of MRCP in detecting the site of biliary obstruction and the cause of biliary obstruction was lightly lower than that one of ERCP, respectively 89.7 and 69.2% vs. 96.2 and 71.8%. Otherwise, the success rate of MRCP was higher than that of ERCP, 98.7 vs. 89.5%. Based on these data, the authors conclude that MRCP can complement ERCP and can actually *replace* ERCP among high-risk patients and in cases of unsuccessful cannulation, conclusions confirmed by Tang et al. in their study focusing on postoperative evaluations. ERCP is either difficult or impossible to perform in patients who have undergone surgery, particularly patients presenting an anastomosis of the bile duct to jejunal or Roux-en-Y loops. MRCP has demonstrated excellent test performance and has resulted in excellent inter-observer agreement for the evaluation of changes in patient anatomy following pancreatobiliary ductal system surgery.

Endocrine PancreaticTtumor

In contrast to most adenocarcinomas, islet cells tumors are hypervascular lesions. In comparison to the surrounding parenchyma these lesions appear brighter, following the early administration of gadolinium. These tumors also show a characteristic marked hyperintense signal in T2 weighted images.

Thoeni RF et al.recently examined 28 patients suspected of having islet cells tumors by using different sequences in MRI, (with and without gadolinium administration), to determine which offers optimal sensitivity. The authors recommend the use of T2-weighted fast SE initially, followed by non-enhanced T1-weighted spoiled GRE with fat-suppression imaging. The use of fast multiplanar spoiled GRE following contrast media administration should be reserved only in those cases in which the basal protocol is not able to show any lesion. The sensitivity of MR in this study for the depiction of functioning islet cells tumors is 85%, with no false-positive results and based on these factors, the authors recommend MR imaging as the modality of choice for detecting lesions of this type.

Cystic Neoplasms

Because MR imaging is so sensitive to fluid, it is not surprising that this modality has great potential to accurately assess these lesions. The cyst fluid improves contrast resolution within the mass, often rendering subtle irregularities of the cyst wall that aid in differential diagnosis between benign and malignant neoplasms and pseudocysts. When combined with MR pancreatography, the duct system can be visualized and the relation of these lesions to the main and branch ducts may be predicted. MRCP, using HASTE sequences, has been shown to be more sensitive than ERCP in the depiction of these lesions.

Serous cystic tumor (synonyms: microcystic adenoma, serous cystadenoma or glycogen-rich cystadenoma) is considered generally a benign neoplasm. However, there are occasional reported cases of serous cystic tumors that behaved in a malignant fashion. Although surgical resection is the treatment of choice, the relative surgical risk should be weighed heavily before resection because its generally benign behavior. It occurs most frequently in elderly patients and has a 1.5:1 female-to-male predominance. The tumor has a slight propensity for occurrence in the pancreatic head but can occur anywhere in the pancreas. Although most serous cystic tumors are isolated lesions, an association does exist with von Hippel-Lindau disease. The large (mean diameter 10-13 cm.), well-circumscribed tumor is often lobulated and contains a central, stellate, calcified scar. In addition, the tumor is composed of multiple small cysts (less than 2 cm in diameter) containing clear fluid and divided by thin septa. The tumor is hypervascular secondary to its rich subepithelial capillary network and has a propensity for hemorrhage. The fluid in the cysts is glycogen-rich with a notable absence of mucin. Imaging studies may show this tumor as either homogeneously solid, or, more commonly, they may demonstrate a predominantly solid mass with multiple small cysts. Some authors have stated that the presence of six or more small cysts within the mass is suggestive of serous cystic rather than mucinous cystic neoplasm. MR images show the well-delineated contour of these tumors, which are usually markedly hyperintense on T2-weighted MR images, although some central areas of low signal intensity may occasionally be seen related to scar formation. T1-weighted MR images show the tumor to be of low signal intensity, except in cases in which the tumor has hemorrhaged. In these cases, the areas of hemorrhage appear hyperintense on T1-weighted MR images.

Mucinous cystic tumors (synonyms: cystadenomas, cystadenocarcinomas, or macrocystic adenomas) range from tumors with malignant potential to frankly malignant mucinous cystadenocarcinoma. These tumors show a marked female predominance, with multiple studies reporting occurrence in female patients in greater than 90% of cases. The typical age at diagnosis is in the 6th decade, contrasting with the older patient seen with microcystic adenomas. Approximately 70-95% of these neoplasms are in the tail or body of the pancreas. Most frequently, these hypovascular tumors are multilocular, but they may be unilocular. They contain mucin and usually have a thick wall, internal septations, solid papillary excretions, and, occasionally peripheral calcifications. MR studies show the unilocular or multilocular nature of this mass. If a mucinous cystic neoplasm is by imaging unilocular and without septations, its differentiation from a pseudocyst may not be possible. MR is advantageous to show internal septations, mural nodules, and solid excrescences in the tumor wall. Scans obtained after the intravenous administration of contrast material may demonstrate enhancement of the septations and peripheral wall. MR images show the contents of these cystic masses to be variable in signal intensity, and this variability is related to either hemorrhage or the proteinaceous nature of the fluid.

Intraductal papillary mucinous tumor (IPMT) is a relatively new and increasingly reported entity (synonyms: mucin-producing tumor, intraductal mucin-hypersecreting neoplasm, mucin-hypersecreting tumor, mucinous ductal ectasia, or ductectatic mucinous cystic tumor). This tumor is one of the mucin-producing tumors of the pancreas and is thought to originate in Wirsung’s duct and its branches. It has either papillary hyperplastic, atypical, or malignant epithelium. On MRI, a dilated main pancreatic duct with uni- or multilocular cystic lesion is typical. Communication between the main pancreatic duct and the cystic lesion may be depicted. Papillary projections or papillary neoplasm may be depicted. The bulging papilla and large caliber of the main pancreatic duct are more common in patients with malignant IPMTs.

Solid pseudopapillary tumor (synonyms: solid-cystic tumor, papillary-cystic tumor, solid and papillary epithelial neoplasm, solid and papillary neoplasm) is a benign or low-grade malignant neoplasm occurring predominantly in young women (range 10-50 years, mean 24 years) without racial predominance. In general, the tumors are found incidentally or in the work-up for abdominal discomfort. Metastases are rare, but local recurrence is possible. After resection of the tumor, the prognosis is excellent with a cure rate of 95%. Solid pseudopapillary tumors are large (range 3-18 cm, mean diameter 10 cm), well-demarcated, solitary masses occuring in every portion of the pancreas. The tumors are encapsulated by a thick, fibrous capsule. Therefore, invasion into adjacent organs is very rare. The tumor stroma is composed of uniform, polygonal cells growing in a monomorphous solid pattern at the periphery and in a pseudopapillary pattern at the center of the lesion. The tumor can be entirely solid. With increasing tumor size solid and cystic components are found side by side due to hemorrhage and necrosis. Furthermore, the cystic changes may predominate resembling also a pseudocyst. The solid parts of the tumor are well vascularized and tend to have calcifications. On MRI, these tumors appear as large heterogeneous masses with a thick, solid capsule enhancing after contrast administration. At the inner margin of the capsule nodular, papillary projections may be present. Calcifications in the periphery of a mass can be seen by CT. Depending on the amount of hemorrhage and necrotic debris, the density of the cystic areas is variable on CT images, as is the signal intensity on T1- and T2-weighted images on MRI.

Pancreatitis

In assessment of acute pancreatitis, MRI, as well as CT, can depict the presence and extent of necrosis and peripancreatic fluid collections. Recently Amano Y et al. demonstrated the superiority of unenhanced MRI over CT in the detection of mild acute pancreatitis. The rationale for using MRI instead of routine CT in these cases is because mild pancreatitis cannot be well visualized by CT and the use of iodinized contrast agents in the first 48 hours may, in fact, impair pancreatic microcirculation.

However, several authors recommend intravenous gadolinium administration in imaging severe acute pancreatitis, particularly for the assessment of pancreatic parenchymal perfusion and presence of necrosis. Otherwise, gadolinium has a good renal tolerance and is better tolerated than the iodinized contrast agents used in CT.

Lecesne et al. has proposed a routine pancreas protocol including T2-W Fast SE, fast-suppressed T1-W Fast SE, and a series of T1-W Gradient echo sequences prior and immediately following gadolinium administration. With this protocol, the authors have reported that MRI is a reliable method for staging acute pancreatitis and is *at least as* accurate as CT in reaching a prognosis. The enlargement of the gland is well demonstrated on any sequence. Parenchymal edema is better shown on unenhanced T1-W images. Pancreatic enhancement is maximal within 20-40 seconds after Gd administration, and the extent of parenchymal necrosis is well demonstrated on sequential, multi-slice acquisition obtained during the first 1-2 min after Gd-injection. T2-W sequences are the most sensitive in demonstrating fluid collections.Despite these results, CT retains several advantages: CT is widely accessible and less costly than MRI and is more sensitive in detecting small gas bubbles and calcifications. However, MRI combined with MRCP has become important in the evaluation of patients with suspected biliary pancreatitis. MRI combines the advantages of cross-sectional imaging techniques, such as ultrasound and CT, with the capability to visualize the pancreatic duct as in ERCP.

The role of MRCP in chronic pancreatitis is still controversial. The experts have predicted that MRCP will replace diagnostic ERCP for the evaluation of pancreatic duct. MRCP has the following advantages over ERCP: it is a non-invasive technique, requiring no anesthesia, no medication and no ionizing radiation; there is no increased risk of pancreatitis; it can be performed on patients with altered pancreaticobiliary system morphology following prior surgery; and in patients with complete obstruction of main pancreatic duct MRCP can demonstrate the upstream anatomy and periductal abnormalities. Otherwise, ERCP is superior in demonstrating mild main pancreatic duct and side-branch abnormalities because of its higher spatial resolution. Moreover, it is able to directly visualize the papilla; obtain pancreatic juice samples; and allow therapeutic maneuvers. A study by Sica et al. compared ERCP and MRCP in acute and chronic pancreatitis. In this study MRCP revealed 91% of the pancreatic duct segments visualized at ERCP. Ninety-two percent of duct segments seen at MRCP were correctly interpreted, using ERCP as the gold standard. Several centers have investigated functional MR pancreatic evaluation by obtaining MRP images before and after intravenous secretin administration. In particular, the degree of enlargement of the main pancreatic duct and the pattern of duodenal filling, following the stimulation of secretin, have been examined. Images collected over a 10- to 15- minute period following secretin administration show improved visualization of the pancreatic duct and its side branches. Furthermore, the volume of effluent into the duodenal lumen can be graded, allowing a relative estimation of the exocrine reserve [41]. Nanashima A. et al. recently confirmed the utility of functional MR following secretin administration in evaluating severe pancreatic exocrine dysfunction. The secretin-induced changes in pancreatic juice secretion using T2-enhanced MR images were measured in 22 patients. The results showed that in patients with severe pancreatic exocrine dysfunction, no increase in secretion is visible following secretin injection.

An area of difficulty for all imaging modalities has been differentiating focal pancreatitis from pancreatic adenocarcinoma. Although several studies in the past have suggested that MRI can help differentiate these two pathologies, especially with respect to focal or diffuse changes in signal intensity and contrast enhancement features [39]; a recent study of 24 patients with pancreatic cancer and 7 patients with chronic pancreatitis showed that MRI could not reliably differentiate the two conditions. Mn-DPDP may have the potential to distinguish pancreatic carcinoma from chronic focal pancreatitis [24], but further studies involving a large number of patients are recommended.

Conclusion

CT continues to be the most effective modality for the initial evaluation of patients with a suspected pancreatic carcinoma. Additional imaging procedures, such as MRI and MRCP and PET scanning are best reserved for patient who cannot undergo a contrast-enhanced CT or for patients in whom the HCT shows equivocal findings.

Contrast-enhanced CT scan plays a critical role in acute pancreatitis because it provides early diagnosis of the disease, designates the severity of illness, detects associated complications, and ensures efficacy in percutaneous therapy. Otherwise, MRI has proven to be an accurate imaging alternative for acute pancreatitis.

Magnetic resonance imaging with MRCP has been adopted as the primary imaging technique in the diagnosis of chronic pancreatitis in several centers.

References

- Amano Y, Oishi T, Takahashi M. Nonenhanced magnetic resonance imaging of mild acute pancreatitis. Abdom Imaging 2001; 26: 59-63.
- Arslan A, Geitung JT, Viktil E, et al. Comparison of 2D single-shot turbo spin-echo MR cholangiopancreatography with endoscopic retrograde cholangiopancreatography. Acta Radiologica 2000; 41: 621-626.
- Cantisani V, Mortele KJ, Levy A, et al. MR Imaging features of solid-pseudopapillary tumor of the pancreas in adult and pediatric patients. AJR 2003;181:395-401.
- De Backer AI, Mortele KJ, Ros PR, et al. Chronic pancreatitis: diagnostic role of computed tomography and magnetic resonance imaging. JBR-BTR 2002;85 :304-310.
- Gabata T, Matsui O, Kadoya M, et at. Small pancreatic adenocarcinoma: efficacy of MR imaging with fat-suppression and gadolinium enhancement. Radiology 1994; 193: 683-688.
- Ichikawa T, Haradome H, Hachiya J, et al. Pancreatic ductal adenocarcinoma: Preoperative assessment with helical CT versus dynamic MR imaging. Radiology 1997; 202: 655-662.
- Johnson PT, Outwater EK. Pancreatic carcinoma versus chronic pancreatitis: dynamic MR imaging. Radiology 1999; 212: 213-218.
- Kanematsu M, Shiratori Y, Hoshi H, et al. Pancreas and Peripancreatic Vessels: Effect of Imaging Delay on Gadolinium Enhancement at Dynamic Gradient-Recalled-Echo MR Imaging. Radiology 2000; 215: 95-102.
- Kato J, Kawamura Y, Watanabe T, et al. Examination of intra-gastrointestinal tract signal elimination in MRCP: Combined use of T1-shortening positive contrast agent and single-shot fast inversion recovery. J Magn Reson Im 2001; 13: 738-743.
- Khurana B, Mortele KJ, Glickman JN, et al. Macrocystic serous adenoma of the pancreas: radiologic-pathologic correlation. AJR 2003;181:119-123.
- Kim T, Murakami T, Takamura M, et al. Pancreatic mass due to chronic pancreatitis: Correlation of CT and MR imaging features with pathologic findings. Am J Roentgenol 2001; 177: 367-371.
- Kim TK, Han JK, Kim SJ, et al. MR colangiopancreatography: Comparison between half-Fourier acquisition single-shot turbo spin-echo and two-dimensional turbo spin-echo pulse sequences. Abdom Imaging 1998; 23: 398-403.
- Lecesne R, Laurent F, Drouillard J, et al. Chronic pancreatitis. In: Baert AL. Delorme G Van Hoe L editors. Radiology of the pancreas, Second ed. Heidelberg: Springer-Verlag 1999: 145-80.
- Lecesne R, Tourel P, Bret PM, et al. Acute pancreatitis: interobserver agreement and correlation of CT and MR cholangiopancreatography with outcome. Radiology 1999; 211: 727-735.

- Malcom PN, Brown JJ, Hahn P, et al. The clinical value of ferric ammonium citrate: a positive oral contrast agent for T1-weighted MR imaging of the upper abdomen. J Magn Reson Im 2000; 12: 702-707.
- Matos C, Metens T, Deviere J, et al. Pancreatic duct: Morphologic and functional evaluation with dynamic MR pancreatography after secretin stimulation. Radiology 1997; 203: 435-441.
- Mayosmith WW, Scima W, Saini S, et al. Pancreatic enhancement and pulse sequence analysis using low-dose mangafodipir trisodium. Am J Roentgenol 1998; 170: 649-652.
- Mortele KJ, Ji H, Ros PR. CT and magnetic resonance imaging in pancreatic and biliary tract malignancies. Gastrointest Endosc 2002;56(6 Suppl):S206-212.
- Mortele KJ, Wiesner W, Cantisani V, et al. Usual and unusual causes of extrahepatic cholestasis: assessment with magnetic resonance cholangiography and fast MRI. Abdom Imaging 2004;29:87-99.
- NanashimaA, Yamaguchi H, Fukuda T, et al. Evaluation of pancreatic secretion after administration of secretin: Application of magnetic resonance imaging. Journal of Gastroenterology ann Hepatology 2001; 16: 87-92.
- Nishiharu T, Yamashota Y, Abe Y, et al. Local extension of pancreatic carcinoma: Assessment with thin-section helical CT versus breath-hold fast MR imaging: ROC analysis. Radiology 1999; 212-445-452.
- Peters HE, Vitellas KM. Magnetic resonance cholangiopancreatography (MRCP) of intraductal papillary-mucinous neoplasm (IPMN) of the pancreas: case report. Magn Reson Imaging 2001;19(8):1139-43.
- Rieber A, Tomczak R, Nussle K, et al. MRI with mangafodipir trisodium in the detection of pancreatic tumours: comparison with helical CT. BJR 2000; 73: 1165-1169.
- Robinson PJA, Sheridan MB. Pancreatitis: computed tomography and magnetic resonnace imaging. Eur Radiol 2000; 10: 401-408.
- Schwartz LH, Coakley FV, Sun Y, et al. Neoplastic pancreatobiliry duct obstruction: Evaluation with breath-hold MR colangiopancreatography. AJR Am J Roentgenol 1998; 170: 1491-1495.
- Scott J, Martin I, Redhead D, et al. Mucinous cystic neoplasms of the pancreas: Imaging features and diagnostic difficulties. Clin Radiol 2000; 55: 187-192.
- Semelka RC, Kroeker MA, Shoenut JP et al. Pancreatic disease: prospective comparison of CT, ERCP and 1.5 Tesla MR imaging with dynamic gadolinium enhancement and fat suppression. Radiology 1991; 181: 785-791.
- Sica GT, Braver J, Cooney MJ, et al. Comparison of endoscopic retrograde cholangiopancreatigraphy with MR cholangiopancreatography in patients with pancreatitis. Radiology 1999; 210: 605-610.
- Sugiyama M, Atomi Y, Hachiya J. Intraductal papillary tumors of the pancreas: Evaluation with magnetic resonance colangiopancreatography. Am J Gastroenterol 1998; 93: 156-159.
- Tang Y, Yamashita, Arakawa A, et al. Pancreaticobiliary ductal system: value of half-Fourier rapid acquisition with relaxation enhancement MR

cholagiopancreatography for postoperative evaluation. Radiology 2000; 215:81-88.
- Thoeni RF, Mueller-Lisse UG, Chan R, et al. Detection of small, functional islet cell tumors in the pancreas: Selection of MR imaging sequences for optimal sensitivity. Radiology 2000, 214: 483-490.
- Ward J, Chalmers AG, Guthrie AJ, et al. T2-weighted and dynamic enhnaced MRI in acute pancreatitis: comparison with contrast-enhanced CT. Clin Radiol 1997; 52: 109-114.